Radioisotopic Terrestrial Generators Multiwatt

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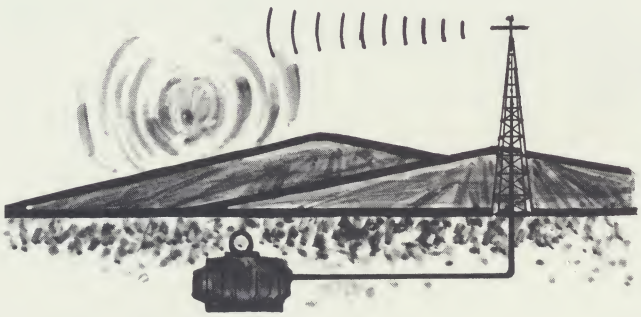
NUMEC radioisotopic thermoelectric generators have a broad range of applications. They meet routine or unusual power requirements for 1 to 20 watts and are ideally suited for unattended or difficult to reach locations.



Typical Power Applications

Signal generation
Detection devices
Navigational aids
Emergency power
Telemetry stations
Weather stations
Sounding devices

Some of the features of NUMEC radioisotopic thermoelectric generators are:

Reliability

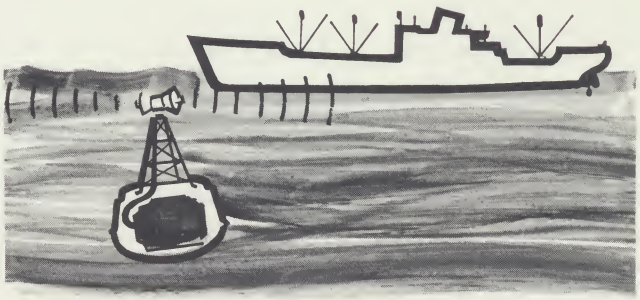
Maintenance free static system
Thermocouple redundancy
Long power life

Versatility

Power flexibility 1-20 watts
Designs for environmental extremes
Size and weight

Safety

Total Isotopic containment
Complete biological shielding



Principles of Operation

The standard models of NUMEC Radioisotopic Thermoelectric Generators convert thermal energy released by radioisotopic decay directly to electrical power. Based on the Seebeck Effect, electrical voltage is created by joining two dissimilar conductors (p, n,) in a closed circuit and maintaining the two junctions at different temperatures. (Figure 1)

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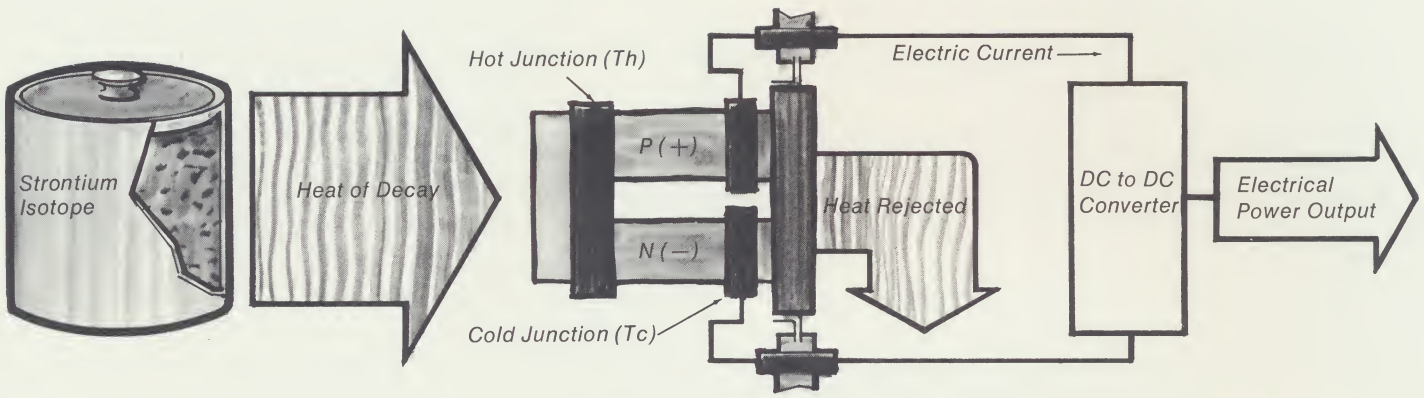


Direct Energy Conversion Cycle (Figure 1)

The thermal energy flows through the thermocouples from the hot junction (Th) to the cold junction (Tc) where it is rejected to the environment through the external shell. This thermal energy flow creates a voltage which causes a current flow. This current flow generates useful power in the form of low voltage and high current which is drawn from the generator by applying the voltage generated by the series connected modules to an external load or to a DC to DC converter. This solid state DC to DC converter steps up the output voltage to supply the voltage requirements for electronic equipment.

Standard NUMEC Models

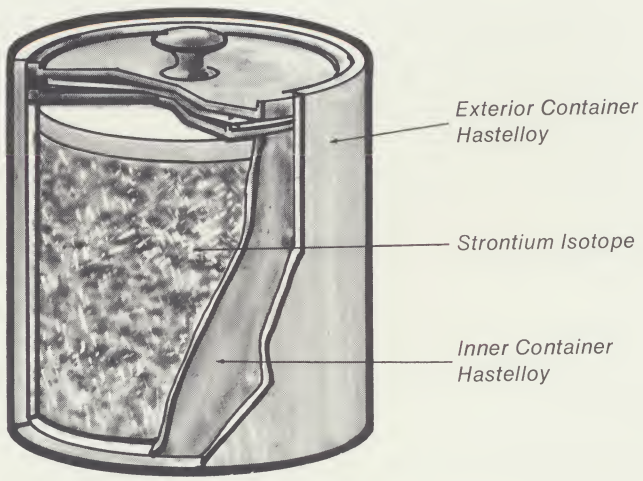
The standard NUMEC models generate a minimum power output of 4 watts for 5 years. This output is typically converted to high voltages by a solid state DC to DC converter which can provide any single output voltage between 6 to 30 volts or a dual output, whichever is desired.

The basic design is flexible in that the standard models may be modified for power levels up to 20 watts (or intermediate power levels) merely by increasing the quantity of isotope and varying the number or area of modular thermoelectric couples.

Radioisotopic Heat Source

The radioisotopic heat source of the standard generators is the 28 year half-time strontium 90 isotope in either the oxide or titanate form. To ensure absolute safety from corrosion caused by the isotope or the environment, the isotope is doubly encapsulated in superalloy materials as shown in Figure 2.

Isotope Encapsulation (Figure 2)



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Biological Shielding

Optional shielding materials of tungsten alloy, depleted uranium or lead may be selected. The choice of shielding materials is governed by the customer's operational requirement, system envelope or weight constraints and considerations of system cost.

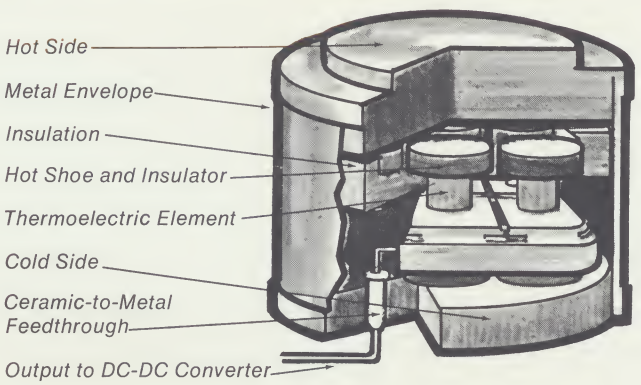
This shielding reduces the radioisotopic exterior surface gamma radiation to absolutely safe biological levels.

Thermoelectric Materials and Modules

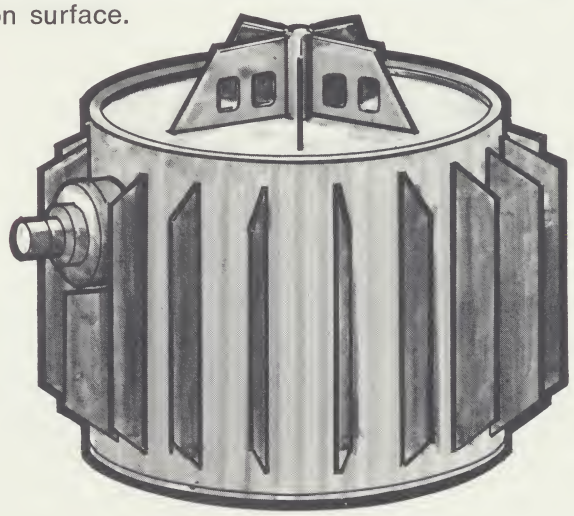
The standard designs utilize lead telluride materials for thermoelectric elements. These elements are arranged in modules (Figure 3) to provide double redundancy for complete system reliability as well as design flexibility (i.e., the number of modules or thermocouple area can be varied to provide various power levels).

To insure maximum efficiency of the individual modules (through reduction of thermal gradients) brazed connections are used throughout the heat path and high performance inorganic insulation surrounds the couples.

Thermoelectric Module (Figure 3)



In operation, thermal energy enters the module at the hot side, flows through the thermocouple, and exits at the cold side. The thermal gradient thus created, across the dissimilar conductors (p, n) in series-parallel arrangement, creates a voltage which causes a current flow to the DC to DC converter and then to the load. The thermal energy which is not converted to electrical power is rejected to the environment at the external heat rejection surface.



Typical Generator Assembly (Figure 4)
(Sub-surface Operating Unit)

Generator Assembly

The radioisotopic heat source and the thermoelectric modules are surrounded by a high performance insulation (to minimize heat losses) and a hermetically sealed shell. This shell is designed for structural strength and corrosion resistance so that it will withstand the environmental extremes whether operating in mountain regions or the submerged depths of the continental shelves. The same containment shell serves as the heat rejection surface for removal of heat not converted to electrical energy.

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Typical Terrestrial Generator Specifications

Configuration	RTG-1T	RTG-2T
Operating Life	5 years	5 years
Environment	Underground or air	Underwater
Output Power	4 watts prior to D.C. to D.C. conversion at end of 5 years	4 watts prior to D.C. to D.C. conversion at end of 5 years
Isotope	SrO or $SrTiO_3$	SrO or $SrTiO_3$
Shielding	Tungsten Alloy	Tungsten Alloy
Shell Material	304 (Clad) stainless steel	Hastelloy-C or 316 stainless steel
Size	16″ high x 14″ diameter (cylindrical)	16″ diameter (spherical)
System Weight	300 pounds	600 pounds
Applications	Telemetry stations Emergency transmission Lights, beacons, signals Observation towers Pipeline monitoring Cathodic protection Weather stations	Underwater signals or beacons Navigational aids Sounding devices Oceanographic sampling Current detection Antisubmarine warfare listening devices

Custom Designs For Specific Applications

NUMEC has designed generators for space and terrestrial applications featuring a variety of power requirements, isotopes and conversion systems. Design parameters for the following are readily available and can be furnished upon request.

Power Range	Microwatt to Kilowatt
Energy Conversion System	Semi-conductor Thermocouples Metallic Thermocouples Thermionic Cascaded Thermionic-Thermoelectric
Isotopes	Pu 238, Po 210, Am 241, Pm 147, Tl 204, Sr 90, Co 60, Cs 137

NUMEC would welcome an opportunity to discuss your requirements and to provide designs conforming to your specific operational restraints. Please write or phone:

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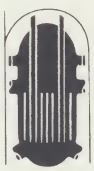
Product Manager
Energy Conversion Division
Apollo, Pennsylvania 15613

Phone 412/472-8411



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Radioisotopic Terrestrial Generators Milliwatt

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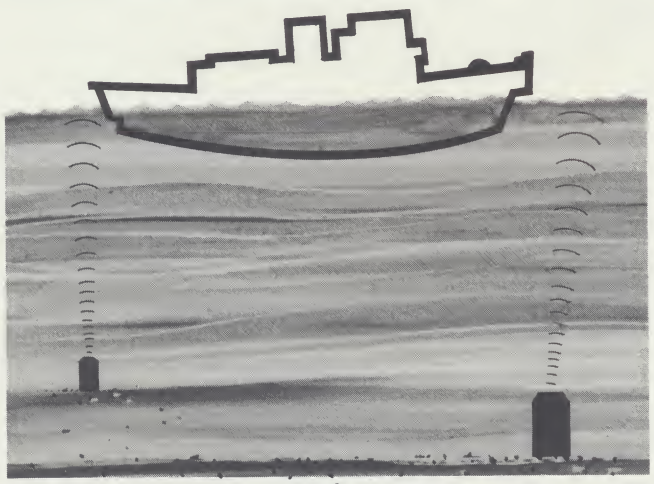
The NUMEC line of milliwatt radioisotopic thermoelectric generators has a broad range of land and oceanographic applications. These units can serve as the primary or auxiliary power sources for power requirements in the entire milliwatt range. This line of generators is ideal for safe, maintenance-free, unattended operation.

Position marking for underwater construction.



Some of the outstanding features of the NUMEC milliwatt generators are:

Reliability

Maintenance-Free Static System
Highly Shock Resistant Couples
Long Power Life

Versatility

Power Flexibility
Unaffected by Environmental Extremes
Compact and Lightweight
Require No Power Conditioning

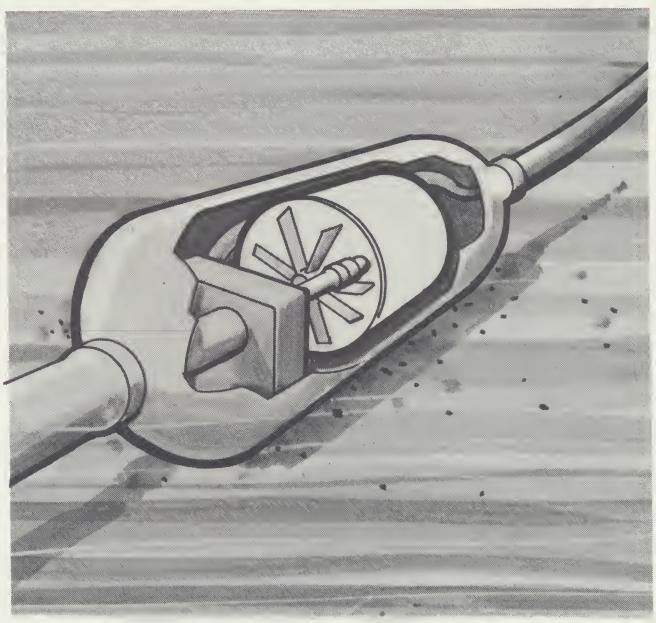
Safety

Absolute Isotope Containment
Complete Biological Shielding

Typical Power Applications

Navigational Aids
Position Markers and Beacons
Signal Generation
Meters, Counters, Detectors, Gauges
Lights or Signals
Battery Trickle Charge
Capacitor Trickle Charge

Instrumentation power i.e., Submarine Cable Repeater.



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Radioisotopic Terrestrial Generators Milliwatt

Safety

To assure absolute safety, even in the most corrosive environments, the heat source of NUMEC's milliwatt generators is doubly encapsulated in proven superalloy materials. The encapsulated heat source is, in turn, surrounded by biological shielding to reduce the surface dose rate to safe operating levels. A final envelope, hermetically sealed, surrounds the entire generating system.

Reliability and Design Flexibility

As a static system, the radioisotopic thermoelectric generator has no moving parts requiring maintenance or replacement during the design life. This allows operation in unattended environments, e.g., deep ocean, for extended periods of time without costly maintenance.

Flexibility in the design of the radioisotopic power generator permits an increase or decrease in the basic power levels by changing the isotope quantity and thermocouple area. In addition, generator configurations may be modified (to fit an unusual system envelope, for example) either through the choice of alternate shielding materials or the development of a specific design to meet operational requirements.

Typical Milliwatt Specifications

Configuration	RTG-3T	RTG-4T	RTG-5T
Size	10″ x 11″	7″ x 8″	3″ x 4″
Output	100 Milliwatts @ 6-8 Volts	100 Milliwatts @ 6-8 Volts	100 Milliwatts @ 6-8 Volts
Life—years	5 years	5 years	10 years
Isotope	Sr-90	Sr-90	Pu-238
Shield	Lead	Depleted Uranium or Tungsten alloy	None
Thermoelectrics	Metallic	Metallic	Metallic
System Weight	340 lbs.	170 lbs.	2 lbs.
Surface Activity	200 mr/hr	200 mr/hr	Negligible

Custom Designs for Specific Applications

NUMEC has developed custom designs for varying customer applications. These designs have featured a wide range of power levels, isotopes and energy conversion systems. Design parameters for the following are readily available and can be furnished upon request:

Power Range	Microwatt to Kilowatt
Energy Conversion System	Semi-conductor Thermocouples Metallic Thermocouples Thermionic Cascaded Thermionic-Thermoelectric
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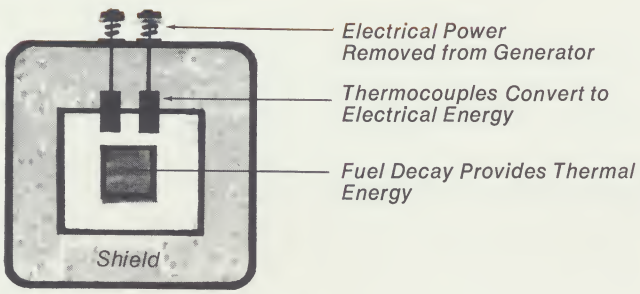
The milliwatt radioisotopic power generator may be used to trickle charge a conventional power system. In this application, the operating life of a battery (which may be the primary power source) is not dependent upon the initial battery charge. Thus, the combination of radioisotope power and conventional power can increase the expected useful life of the system many-fold and enhance the system's reliability and design versatility at reduced operating costs.

For high reliability and efficiency, capacitors may also be used to store electrical power produced by the milliwatt generator. This approach is particularly beneficial where pulsing characteristics are required. Pulsed power in the multi-watt range can be generated with this combination, depending upon pulse duration and pulse repetition rate requirements.

Thermoelectric Energy Conversion (Figure 1)



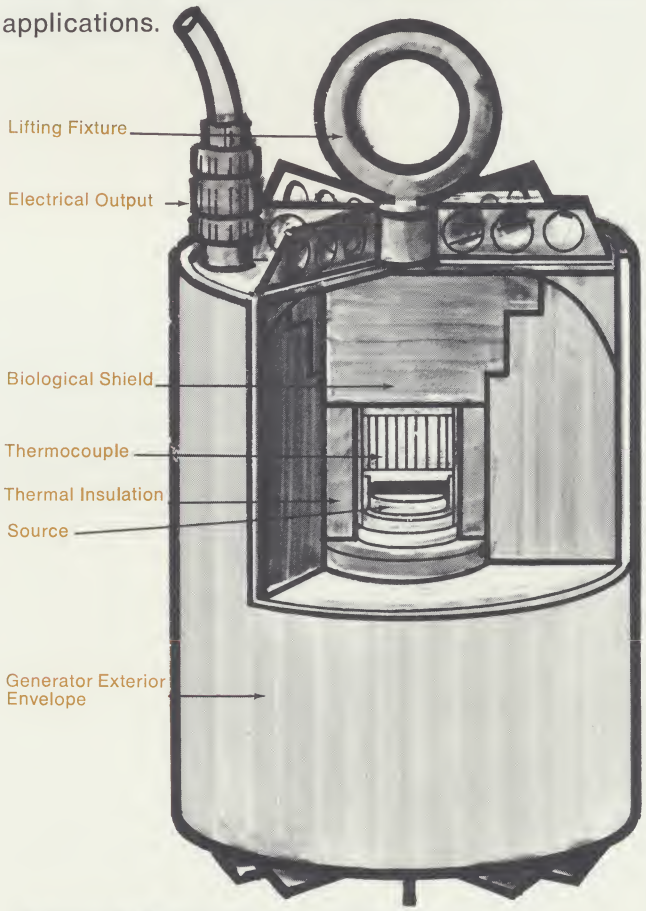
Principles of Operation

The thermal energy released through decay of the radioisotopic fuel is directly converted to electrical power by means of the Seebeck effect. (The creation of electrical voltage when two dissimilar metals are joined in a closed circuit and the two junctions are maintained at different temperatures.) The electrical power is removed at the terminals, ready for use (Figure 1).

Radioisotopic Thermoelectric Generator

This radioisotopic power generator (shown in Figure 2) utilizes Strontium 90 (half life — 28 years) as the isotopic heat source. This doubly encapsulated heat source is surrounded, in turn, by high performance vacuum insulation, biological shielding and an exterior hermetically sealed envelope of corrosion resistant metal.

Electrical leads pass through the envelope directly to the electrical load. NUMEC's milliwatt generators require no additional power conditioning equipment for the vast majority of power applications.



Typical Milliwatt Generator *(Figure 2)*

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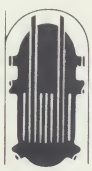

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